Absorption capacity of major urban afforestation species in northeastern China to heavy metal pollutants in the atmosphere

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Abstract: Totally 24 arbor tree species and 6 shrub species were measured on their absorption capacities to heavy metal Pb, Cd, Cr, and Hg by collecting and analyzing the leaves of trees along different streets in Harbin city in Sept. to Oct. of 2003. The results showed that all the measured species had certain absorbency to the pollutants (Pb, Cd, Cr and Hg), but there existed significant difference in absorption capacity for different species to different pollutants. The measured tree species were classified into three categories by their absorption quantum of heavy metal pollutants. Among the species measured, *Betula platyphylla*, *Ulmus pumila* var. *pendula*, and *Prunus persica* f. *rubro-plena* had high capacity in absorbing Pb; *Populus xiaohei*, *P. nigra* var. *italica*, *P. alba* × *P. berolinensis* and *Salix matsudana* had had high capacity in absorbing Cd; *Phellodendron amurense*, *Syringa oblata*, *Salix matsudana*, *Pinus tabulaeformis* var. *mukdensis*, *Picea koraiensis*, *Prunus persica* f. *rubro-plena*, *P. triloba* and *Acer negundo*, etc. had high capacity in absorption of Cr; *Prunus triloba*, *Quercus mongolica*, *Salix matsudana*, *Sambucus williamsii*, *Pyrus ussuuriensis* and *Spiraea fritschiana* were good at absorption of Hg. This study might offer scientific foundation for selection of urban afforestation species in different polluted conditions caused by heavy metals.

Keywords: Greening tree species; Heavy metal; Pollutants; Plumbum; Cadmium; Chromium; Mercury; Absorptivity
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Introduction

With the quick development of many heavy industries, more and more synthesis materials emit pollutants into the atmosphere. Plumbum (Pb), cadmium (Cd), chromium (Cr) and mercury (Hg) are important environmental pollutants of the atmosphere. Petrol with Pb used in all kinds of vehicles is one of the sources of Pb of the atmosphere in the city. In addition, industrial production, especially paint, battery and food production are the sources of Pb. The source of Cd exists in enamel, plastics, paint, dye and some wasteful liquid, etc. The source of Cr mainly exists in carbon monoxide, sulfur dioxide and dust, etc. during the course of coal burning and the smoke and additional heat in the fire power. The sources of Hg come from coal burning for power, heat production, and other energy production, etc, in addition, cement production, chemical production, waste and dust are also the sources of Hg. The pollutions from these four kinds of heavy metal are very harmful to our lives. Therefore, we should take natural methods to control environmental pollutants of the atmosphere (Huang *et al.* 1983). Greening tree species have obviously improving effects on environmental pollution. They can absorb pollutants of the atmosphere by stomata of leaves and lenticel of branches, and then change pollutants into nontoxic substance by oxidization restoration reaction. In fact, plants can purify atmosphere by absorbing, befalling and accumulating pollutants of the atmosphere (Huang *et al.* 1981; Lu *et al.* 2002). In general, accumulated pollutants in plant leaves have direct proportion relationship with the density of pollutants of the atmosphere. The absorption content of greening tree species to Pb, Cd, Cr and Hg is analyzed and compared among different tree species. In capacity were selected to measure different absorption capacity to different pollutants in greening tree species. The results can offer theoretical foundation for selection of reasonable greening tree species (Jiang *et al.* 1992).

Materials and methods

Tree species

Total of 30 experimental species, of which 24 species are woody tree and 6 species are shrub, were measured in the study, including *Larix gmelinii* (Rupr.) Rupr., *Picea koraiensis* Nakai, *Pinus sylvestris* L.var. *mongolica* Litv., *Pinus tabulaeformis* Carr. var. *mukdensis* Uyeki, *Sabina chinensis* (L.) Ant., *Populus alba* L. ×*P. berolinensis* Dipp., *P. nigra* L. var. *italica* (Moench) Koehne, *P. xiaohei* T.S. Hwang ex C. Wang et Tung, *Salix matsudana* Koidz., *Betula platyphylla* Suk., *Quercus mongolica* Fisch., *Ulmus pumila* L., *U. pumila* L.var. *pendula* (Kirchn.) Rehd. (The edition Committee of Plant Flora of Liaoning 1985), *Prunus armeniaca* L., *P. maackii* Rupr., *P. salicina* Lindl., *P. persica* (L.) Batsch f. *rubro-plena* Schneider, *P. triloba* Lindl., *Pyrus ussuriensis*

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Maxim., *Rosa xanthina* Lindl., *Sorbaria sorbifolia* (L.) A.Br.ex Aschers., *Spiraea fritschiana* Schneid., *Phellodendron amurense* Rupr., *Euonymus maackii* Rupr., *Acer negundo* L., *Fraxinus manshurica* Rupr., *Ligustrum suave* (Kitag.) Kitag., *Syringa oblata* Lindl., *S. reticulata* (Blume) Hara var.*mandshulica* (Maxim.) Hara and *Sambucus williamsii* Hance (Chou *et al.* 1986).

Sample collection

The collected samples come from the leaves of 30 greening tree species growing better on both sides of the main roads in Harbin City in Heilongjiang Province. They included Hexing Road (two circle road), Haping Road (from the center of the city to suburb), Heping Road (in the center of the city), Zhongshan Road (in the center of the city), Jiangnan Road (in the suburb). These five roads have different source of pollution and pollution extent. The leaves of every tree species for 3-5 stubs from different directions in the same area were collected in parallel and crossing ways according to the same principles, and then leaves without diseases were mixed according. Tree leaves were collected from the base of tree crown (Liu *et al.* 2003) from September to October in 2003.

Measurement method

Leaves were washed out dust and miscellaneous articles on the surface, dried in the air and placed in the oven of 60 °C until dried up, and then crumbled. Even samples of 1.0000g were measured and dissolved by liquor of HNO_3—$HClO_4$. The absorption contents of leaves to Pb, Cd, Cr and Hg were measured by the method of GGX-9A AAM. The absorption contents of leaves to Hg were measured by the method of AFM.

The absorption quantum of different species to the four kinds of elements measured was classified into three categories (Table 1).

Table 1. Category standard for absorption quantum of different elements $mg \cdot kg^{-1}$

Category	Plumbum	Cadmium	Chromium	Hg
Category I	>10	>0.5	>10	>0.2
Category II	5-10	0.1-0.5	5-10	0.05-0.2
Category III	<5	<0.1	<5	<0.05

Results and analysis

Greening tree species had the capacity to absorb Pb, Cd, Cr and Hg to some extent, but the absorptivity was obviously different for different tree species (Table 2). The absorption quantum of *Betula platyphylla* to Pb was the highest (13.09 $mg \cdot kg^{-1}$) and that of *Rosa x anthina* was the lowest (1.62 $mg \cdot kg^{-1}$) in all the measured tree species. The absorption quantum of *Populus xiaohei* to Cd was the highest (1.269 $mg \cdot kg^{-1}$), and that of *Phellodendron amurense* was the lowest (0.040 $mg \cdot kg^{-1}$) of all the measured tree species. For Cr element, the absorption quantum of *Phellodendron amurense* was the highest (12.26 $mg \cdot kg^{-1}$), and that of *Pinus sylvestris* var. *mongolica* was the lowest (2.08 $mg \cdot kg^{-1}$). As for Hg element, the absorption quantum of *Prunus triloba* was the highest (0.772 $mg \cdot kg^{-1}$), and *Syringa recticulata* was the lowest (0.004 $mg \cdot kg^{-1}$).

In similar areas of pollution and similar pollution extent, the absorption quantum of different tree species to the four kinds of elements was obviously different (Table 3).

Concerning absorption quantum of broad-leaf, coniferous species, arbor as well as shrub species to Pb, Cd, Cr, and Hg, it can be seen from their proportions in the categories with different absorption quantum that the broad-leaf tree species was higher than conifer, and arbor trees were higher than shrubs (Table 4).

Conclusions and discussion

All the measured afforestation species had strong function in absorption of Pb, Cd, Cr and Hg, but the absorption capacity obviously varied with different tree species on different polluted conditions.

Among the species measured, *Betula platyphylla*, *Ulmus pumila* var. *pendula*, and *Prunus persica* f. *rubro-plena* had high capacity in absorbing Pb; *Populus xiaohei*, *P. nigra* var. *italica*, *P. alba* x *P. berolinensis* and *Salix matsudana* had had high capacity in absorbing Cd; *Phellodendron amurense*, *Syringa oblata*, *Salix matsudana*, *Pinus tabulaeformis* var. *mukdensis*, *Picea koraiensis*, *Prunus persica* f. *rubro-plena*, *P. triloba* and *Acer negundo*, etc. had high capacity in absorption of Cr; *Prunus triloba*, *Quercus mongolica*, *Salix matsudana*, *Sambucus williamsii*, *Pyrus ussuuriensis* and *Spiraea fritschiana* were good at absorption of Hg.

Based on the analysis, the species selected for the polluted areas by different elements are *Betula platyphylla*, *Ulmus pumila* var. *pendula*, *Prunus persica* f. *rubro-plena* as woody species *Syringa oblata*, and *Prunus triloba*, *Ligustrum suave*, and *Sorbaria sorbifolia* as shrub species for the polluted area of Pb; *Populus alba*×*P. beroliensis*, *P.xiaohei*, *P. nigra* var. *italica*, *Betula platyphylla*, *Salix matsudana*, and *Sabina chinensis* as woody species, and *Syringa oblata*, *Prunus triloba*, and *Spiraea fritschiana* as shrub species for the polluted area of Cd; *Picea koraiensis*, *Pinus tabulaeformis* var. *mukdensis*, *Salix matsudana* *Prunus persica* f. *rubro-plena*, *Acer negundo*, and *Phellodendron amurense as woody species*, and *Syringa oblata* and *Prunus triloba as shrub species for the polluted area of Cr*, *Salix matsudana*, *Quercus mongolica*, *Sambucus williamsii*, *Pyrus ussuriensis*, and *Betula platyphylla* as woody species, and *Spiraea fritschiana*, *Prunus triloba* and *Ligustrum suave* as shrub species for the polluted area of Hg.

Table 2. Absorption quantum of different tree species to Pb, Cd, Cr, and Hg

Tree species	Absorption quantum / mg·kg^{-1}							
	Plumbum	Category	Cadmium	Category	Chromium	Category	Hg	Category
Larix gmelinii	4.78	III	0.094	III	3.75	III	0.113	II
Picea koraiensis	5.20	II	0.094	III	10.51	I	0.144	II
Pinus sylvestris var. mongolica	3.99	III	0.091	III	2.08	III	0.022	III
Pinus tabulaeformis var. mukdensis	3.83	III	0.070	III	10.83	I	0.154	II
Sabina chinensis	7.74	II	0.493	II	9.78	II	0.067	II
Populus alba × P. berolinensis	6.70	II	0.547	I	5.67	II	0.067	II
Populus nigra var. italica	7.09	II	0.686	I	8.45	II	0.064	II
Populus xiaohei	7.36	II	1.269	I	6.40	II	0.011	III
Salix matsudana	7.83	II	0.734	I	11.27	I	0.320	I
Betula platyphylla	13.09	I	0.333	II	5.22	II	0.181	II
Quercus mongolica	4.89	III	0.149	II	3.85	III	0.402	I
Ulmus pumila	7.97	II	0.128	II	7.08	II	0.051	II
Ulmus pumila var. pendula	11.88	I	0.072	III	7.74	II	0.010	III
Prunus armeniaca	5.45	II	0.078	III	5.47	II	0.087	II
Prunus maackii	6.55	II	0.091	III	7.60	II	0.054	II
Prunus persica f. rubro-plena	10.36	I	0.068	III	10.22	I	0.134	II
Prunus salicina	5.86	II	0.046	III	7.05	II	0.081	II
Prunus triloba	7.51	II	0.133	II	10.18	I	0.772	I
Pyrus ussuriensis	5.68	II	0.088	III	5.16	II	0.212	I
Rosa xanthina	1.62	III	0.078	III	5.65	II	0.065	II
Sorbaria sorbifolia	8.55	II	0.081	III	6.69	II	0.018	III
Spiraea fritschiana	5.03	II	0.125	II	5.14	II	0.208	I
Phellodendron amurense	4.00	III	0.040	III	12.26	I	0.119	II
Euonymus maackii	7.41	II	0.098	III	9.35	II	0.089	II
Acer negundo	7.21	II	0.174	II	10.00	I	0.014	III
Fraxinus manshurica	6.50	II	0.053	III	6.04	II	0.059	II
Ligustrum suave	7.84	II	0.077	III	7.93	II	0.192	II
Syringa oblata	8.93	II	0.106	II	11.62	I	0.017	III
Syringa reticulate var. *mandshulica*	5.35	II	0.078	III	5.82	II	0.004	III
Sambucus williamsii	5.60	II	0.075	III	7.30	II	0.272	I

Table 3. Comparison of absorptivity of different tree species to the four elements measured in different polluted areas

Areas	Plumbum	Cadmium	Chromium	Hg
Hexing Road:	*Ulmus pumila* var. *pendula* > *Ligustrum suave* > *Populus alba* ×*P. beroliensis* > *Picea koraiensis*	*Populus alba* × *P. beroliensis* > *Picea koraiensi* > *Ligustrum suave* > *Ulmus pumila var. pendula*	*Picea koraiensis* >*Ligustrum suave*>*Ulmus pumila* var. *pendula*>*Populus alba* × *P. beroliensis*	*Ligustrum suave* > *Picea koraiensis* > *Populus alba* × *P. beroliensis* > *Ulmus pumila* var. *pendula*
Haping Road	*Sabina chinensis* > *Fraxinus manshurica* > *Sambucus williamsii* > *Phellodendron amurense*	*Sabina chinensis* > *Sambucus williamsii* > *Fraxinus manshurica* > *Phellodendron amurense*	*Phellodendron amurense* > *Sabina chinensis* > *Sambucus williamsii* > *Fraxinus manshurica*	*Sambucus williamsii* > *Phellodendron amurense* > *Sabina chinensis* > *Fraxinus manshurica*
Heping Road	*Syringa oblata* > *Acer negundo* > *Populus nigra* var. *italica* > *Syringa recticulata* var. *mandshulica* > *Pinus tabulaeformis* var. *mukdensis*	*Populus nigra* var. *italica* > *Acer negundo* > *Syringa oblata* > *Syringa recticulata* var. *mandshulica* > *Pinus tabulaeformis var. mukdensis*	*Populus nigra var. italica* > *Acer negundo* > *Syringa oblata* > *Syringa recticulata* var. *mandshulica* > *Pinus tabulaeformis* var. *mukdensis*	*Pinus tabulaeformis* var. *mukdensis* > *Populu snigra* var. *italica* > *Syringa oblata* > *Acer negundo* > *Syringa recticulata* var. *mandshulica*
Zhongshan Road	*Ulmus pumila* > *Quercus mongolica* > *Rosa xanthina*	*Quercus mongolica* > *Ulmus pumila* > *Rosa xanthina*	*Quercus mongolica* > *Ulmus pumila* > *Rosa xanthina*	*Quercus mongolica* > *Rosa xanthina* > *Ulmus pumila*
Jiangshan Road	*Prunus triloba* > *Euonymus maackii* > *Populus xiaohei* > *Prunus salicina* > *Pyrus ussuriensis* > *Spiraea fritschiana*	*Populus xiaohei* > *Prunus triloba* > *Spiraea fritschiana* >*Euonymus maackii* > *Pyrus ussuriensis* >*Prunus salicina*	*Populus xiaohei* > *Prunus triloba* > *Spiraea fritschiana* > *Euonymus maackii* > *Pyrus ussuriensis* > *Prunus salicina*	*Prunus triloba* > *Pyrus ussuriensis* > *Spiraea fritschiana* > *Euonymus maackii* > *Prunus salicina* > *Populus xiaohei*

Table 4. Species composition for different categories of absorption quantum of measured elements

Element	Category	Species number	Proportions of Conifer and Broad-leaf species		Proportions of arbor and shrub species	
			Conifer %	Broad-leaf %	Arbor %	Shrub %
Plumbum	I	3	0	100	100	0
	II	21	9.5	90.5	71.4	28.6
	III	6	50.0	50.0	83.3	16.7
Cadmium	I	4	0	100	100	0
	II	8	12.5	87.5	62.5	37.5
	III	18	22.2	77.8	77.7	22.3
Chromium	I	8	25.0	75.0	75.0	25.0
	II	19	5.3	94.7	73.7	26.3
	III	3	66.7	33.3	100	0
Hg	I	6	0	100	66.7	33.3
	II	17	23.5	76.5	76.5	23.5
	III	7	14.3	85.7	71.4	28.6

The absorption capacities of *Rosa x anthina* and *Pinus tabulaeformis* var. *mukdensis* to Pb were lower in Harbin than that in Beijing (Wen *et al.* 1996; Leng *et al.* 1995; Gao *et al.* 1986), while those of *Salix matsudana, Ulmus pumila, Sabina chenensis, Picea koraiensis, Syringa obalata, Sorbaria sorbifolia, Euonymus maackii and Prunus triloba* to Pb were higher than the same tree species in Beijing. The absorption quantum of *Sorbaria sorbifolia*, *Prunus triloba* and *Rosa xanthina* to Cd was lower than that in Beijing, *Salix matsudana, Ulmus pumila, Sabina chenensis, Picea koraiensis, Syringa obalata, Euonymus maackii* and *Pinus tabulaeformis* var. *mukdensis* were higher than that in Beijing. In our experiment, tree species with a high absorption capacity of Pb and Cd grow better, which showed that those tree species had much higher absorption capacity.

For selecting greening tree species, we should consider not only the absorption capacity of different tree species to the four elements measured, but also the proper arrangement of woody trees and shrubs, conifers and broad-leaved trees.

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